THE IMMORTALITY OF INFUSORIA.

THE ingenious hypothesis that Weismann, the eminent Freiburg professor, promulgated several years ago regarding the vitality of all unicellular beings, but more especially of the Protozoans, is undoubtedly widely known. Weismann maintained that the Protozoans were distinguished from the Metazoans, or organisms composed of a number of cells, by the curious property they possessed of exemption from decay and death. The Protozoans exhibited, in the very words of the German savant, an instance of potential immortality;* that is to say, a natural physiological death did not exist for them; if they perished, it was by accident or chance, extraneous to the laws of their organisation. A great many authors have written upon this subject since Weismann, either in support of his opinion, or in refutation of it, and of them we may mention principally Goette,† Minot,‡ and M. Delboeuf.§

It is to be observed that this idea of potential immortality is not the exclusive property of Weismann. We find it clearly indicated by Ehrenberg. And, moreover, as Bütschli remarks, it is so natural that it ought to occur of itself to the mind of every tolerably thoughtful observer that has devoted his time to the study of the biology of these minute creatures.‖

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* *Ueber die Dauer des Lebens.* Jena, 1882.

† *Ueber den Ursprung des Todes*, 1883.

‡ *La Mort et l'Individualité. (Bulletin Scientifique du Nord*, 1884-85.)

§ *La Matière Brute et la Matière Vivante.* Paris 1887.

‖ *Gedanken über Leben und Tod (Zoologische Anzeige*, Vol. v, 1882), cited by M. Maupas in *Multiplication des Infusoires Ciliés—Arch. de Zool. Experimen.*, No. 2, 1888.

Weismann founded his theory in part upon metaphysical, or at least theoretical, considerations, which we deem it useless to discuss at this point. But it is also supported by observed facts, and these facts it will be profitable to recapitulate from the very onset. The idea of the immortality of Infusoria occurs naturally to the mind when one examines with care what happens when an Infusorian reproduces. We know that the reproduction consists in a bipartition of the body of the animal, and that consequently the parent does not die but lives in the two products of its bipartition. In subsequent multiplications the same phenomenon is always observed to occur, so that the entire substance of the parent is found preserved and living in the individuals to which it gives birth. This process Weismann expressed by the emphatic statement: In multiplication by division there are no corpses. It is wholly otherwise with the metazoans, and the reason of this fundamental difference is easily explained by the comparison of the organisation of the body of a metazoan with that of a protozoan. Whereas the protozoan is represented by a single cell that comprehends all the vital functions, the functions of reproduction as well as those of nutrition and relation, the metazoan, on the other hand, is composed of an aggregation, of a colony of distinct cells, among which a division of labor has been effected varying in complexity with the height that the animal has attained in the classificatory scale. It results from this division of labor that in the metazoan certain cells only—those namely which are called the sexual cells—are entrusted with the office of the conservation of the species, while the various other cells are more especially adapted to the conservation of the individual. When a metazoan reproduces, the sexual cells alone enter into activity, and after having suffered various modifications, the principal one of which is fecundation, the sexual cells become the seat of numerous segmentations that go to constitute a new animal distinct from the one that gave it birth. The moment the parent individual ceases to be blended with the individual it produces, it can perish without imperilling the conservation of the species, and thus it is that death appears in the animal kingdom as a logical consequence of division of labor.

We also know that Weismann, in developing these interesting facts, was led with many other naturalists to establish the doctrine that every metazoan may be considered as made up of two entirely distinct groups of cells: 1) of somatic cells, which represent the individual, and which are invested with the care of its nourishment, its sense-mechanism, its movements, and all the functions that have to do with individual life; and 2) of sexual cells, charged with the office of the maintenance of the species in time. Whereas the somatic cells are destined to perish, the sexual cells on the contrary, multiplying by division after the mode of the reproduction of micro-organisms, represent the protozoan type, which is immortal; and, by the intermediary agency of the fecundated ovum, the sexual cells pass from generation to generation, thus forming a material bond between successive generations. Though we have to succumb to death, there is at least a portion of us that ought not to die, from the fact that it is transmittible to our descendants. Naegeli expressed this idea in a felicitous form, when he compared the species to a creeping branch that sent out at successive points annual buds. The buds, which die, are the individuals—that is the somatic group; while the branch that survives after the death of the buds, and which represents the species, is the system of sexual cells. Weismann, finally, has described the same phenomenon by the expression 'continuity of the germinative plasm.'

A great many discussions have arisen with regard to this germinative plasm; for everything touches upon this domain, and Weismann has conceived a theory that endeavors to explain not only the phenomenon of fecundation, but also that of heredity. I cannot mention here the numerous works upon this subject, and refer the inquisitive reader for a knowledge of the same to a series of lectures by Professor Balbiani that I have epitomized in the *Revue Philosophique* for December 1889.

The theory of the potential immortality of the Infusoria has recently been attacked by M. Maupas, whose observations tend to show that natural death, caused by senescence, does obtain among the Infusoria, and that it is comparable in many points of view to the natural death of the metazoans. The researches of M. Maupas

upon the multiplication of ciliate Infusoria are of a relatively recent date, having appeared in 1888 in Vol. VI. of the "Archives de Zoologie Expérimentale."

It is scarcely necessary to say that the ciliate Infusoria can propagate without previous coition. The agamic mode of reproduction appears to be almost the same, save in a few details, as that which follows coition. It consists in a bipartition or division of the body of the animal along a plan, usually perpendicular to the grand axis of the nucleus, and it is a matter of course that that element takes part in the division at the same time with the protoplasm. These phenomena of reproduction it is possible to study upon a grand scale by supplying Infusoria kept in captivity with abundance of nourishment. The easiest way is to produce a putrid fermentation by means of vegetable fragments crushed and macerated in water. The Infusoria contained in this water find abundant food furnished by the bacteria developed in it, and they therefore multiply in great numbers. By means of appropriate methods of treatment and isolation we are able to follow the phenomenon step by step and to examine what the animal actually becomes after each agamic bipartition.

Weismann, when he laid the foundation of his theory of the immortality of Infusoria, supposed that the development of the Infusoria by bipartition had no limits and could be prolonged indefinitely without injury to the vitality of the protoplasm. Various authors had already made observations which were directly in contradiction with this view. M. Balbiani, in 1860, in a communication entitled, "Observations and Experiments upon the Phenomena of Fissiparous Reproduction among Ciliate Infusoria,"* concludes thus: "one of the most important questions . . . . has been to determine whether this mode of propagation is really unlimited, or whether, after being continued throughout a greater or lesser number of generations, it becomes by degrees enfeebled, finally to disappear completely. . . . . We have established that this mode of propagation has its limits, and ends invariably in one of the

* *C. R. Acad. des Sciences.* Vol. iv. p. 1191.

three following ways: either by the *natural* and almost simultaneous *death* of all the individuals belonging to the same cycle, or by the recurrence of sexual generation leading to the termination of one of the cycles and the commencement of a new cycle, or finally by the phenomenon of encystment, which in fact brings about only a momentary interruption of the process of reproduction by fissiparity." M. Balbiani, apropos of this subject, has called attention to a curious observation made by the celebrated Danish micrographer O. F. Müller, who lived in the last century. Müller had observed that the individuals of any one species most ordinarily found in coition were almost all of small stature But he took them for the young individuals of the species. Now these individuals of small size are in reality the oldest, that is to say, they are the ones that are the result of a great number of successive bipartitions; and it is to be observed, that, in a great many species, in proportion as the bipartitions increase the size of the Infusoria decreases.

In fine, without further concerning ourselves with the history of this question, we see that according to M. Balbiani the agamic reproduction of Infusoria has its limits, and that, when coition, that is to say fecundation, does not intervene, it may terminate by the natural death of the individuals or in certain species by encystment.

The chief new element contained in the recent researches of M. Maupas, which were made twenty years after the date of the preceding investigations, consists in his study of the various phenomena of senescence that the Infusoria after a long series of bipartitions present. M. Maupas has established that there exists in the Infusoria no part, no element, that by itself and by its own faculties, can live and be maintained indefinitely. The first outward sign of degeneration is manifested in a reduction of size. The individuals, according as the number of generations increases, become smaller and smaller. With *Stylonichia pustulata*, which in the normal state measures one hundred and sixty μ, the size of the body is seen gradually to fall to one hundred and thirty-five, one hundred and ten, seventy, and even to forty μ. When the effects of senescence

become marked, the animal in its external organs undergoes atrophies and new and more profound degenerations. In *Stylonichia pustulata* the vibratile buccal apparatus becomes gradually atrophied and partly disappears, and in all species the body is reduced and becomes more and more shrunken, assuming forms and contours very far removed from the specific type. The degeneration of the nuclear apparatus at once begins. The first modifications affect the accessory or attendant nucleus, a cut of which will be found at page 118 of my work on Micro-organisms,* and of which the principal function seems to be the maintenance and conservation of the species, and which, therefore, ought to be considered as the real substratum of the immortal plasma. Far from enjoying the attribute of eternal youth, the accessory nucleus seems on the contrary to be affected with a weakness greater and more premature than that of the other parts of the organism. In fact it is this organ that is first atrophied and that disappears under the influence of senile degenerescence. Then, in its turn, the principal nucleus is affected. It takes, according to the species, a different form. Now it diminishes in volume, now it divides into two minute bodies that assume irregular contours, and at other times it assumes a ribbon-like shape.

It is interesting to note that even after the disappearance of the accessory nucleus, whenever the principal nucleus still subsists, the Infusoria continue to live and divide by fission. This life, says M. Maupas, has some features of abnormality about it, since it has become wholly purposeless. The animals still live an individual life, but they are dead to the life of the species.†

In concluding upon this point, I must mention the reservations that may be entertained with regard to the exactitude of the preceding observations and the value of the method employed in their attainment. A competent critic has remarked that it is difficult to assume that nine hundred and thirty-five specimens of the genus *Stylonichia* could find the gases necessary for the support of life,

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* English translation by The Open Court Pub. Co., Chicago. Longmans & Co., London. † Page 262.

seeing that M. Maupas kept them under the same stage where they only had at their disposal a mass of water equal to one hundred cubic millemetres; and it may thus be asked whether the phenomena of senescence produced under these special conditions were not pathological. This criticism seems to be especially strengthened by the fact, that according to M. Maupas, the animalcula placed beneath the shield, all finally congregate at the edge of the preparation, evidently to seek there the air of which they are in need.

If we took our stand, however, upon the facts before cited we could conclude without hesitation that the celebrated thesis of Weismann regarding the immortality of the ciliate Infusoria had been overthrown. But the phenomena are not presented with this simplicity. When the vitality of the Infusoria has become weakened by a considerable number of agamic reproductions, and the animalcule is upon the point of dying a natural death, a new biological phenomenon can intervene, rejuvenating the animal and rendering it capable of reproducing itself anew for a long series of generations. That phenomenon is fecundation.

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In our work upon Micro-Organisms we have spoken at length of the material process of fecundation in ciliate Infusoria, and of the phenomena preliminary to it, following as our guide the observations of Balbiani, Gruber, Bütschli, and Engelmann. It will be necessary to recur here to that subject and to supplement our preceding exposition with some important details. Moreover, recent researches, added to other older ones, afford us interesting information with regard to the conditions and determining causes of conjugation and also of the significance of fecundation itself.

We have seen above that according to M. Balbiani an active period of agamic bipartition in Infusoria can terminate in a period of conjugation; a circumstance which produces in effect a cyclical alternation between agamic generations and a sex-generation. The very word cycle is used in the observations of M. Balbiani. M. Maupas elevated this observation of M. Balbiani to the rank of a method; using, in order to procure the great number of coitions necessary for his investigations, the following process. He

placed the Infusoria in water in which he had produced a putrid fermentation. The Infusoria, thanks to the abundance of the nutriment developed in great numbers. While thus swarming they were lifted out with a drop of water, which was kept upon the stage in a moist chamber. The Infusoria there continued to grow larger and multiply; but by reason of their great numbers it was not long before they exhausted the food brought with them in the drop of water. When the last remains of their nutriment had disappeared they were seen in the majority of cases to seek each other and to copulate.

According to M. Maupas, it is not solely the weakness produced by a series of bipartitions, but, in addition to that and more particularly, the scarcity of food, that excites in the ciliate Infusoria the conjugal appetite. The epidemics of conjugation of which the authors speak, are not otherwise explainable. M. Maupas even says, that when a number of pairs are about to copulate, it is only necessary to give them food to put an end to their conjugation. Scarcity, that author further remarks, ought evidently not to modify in any essential the internal organic state of the Infusoria in question; no more indeed than the opposed condition, that is, an abundance of rich food (page 403 of his memoir). But in the first case they copulate without any ado; in the second, they refuse to do so entirely. Rich alimentation deadens the conjugal appetite; fasting, on the contrary awakens and excites it. There exists moreover, according to the author last mentioned, in ciliate Infusoria, a particular period beyond which fecund coitions cannot take place. It is what he calls the period of karyogamic maturity. Thus, in *Leucophrys*, for example, fecund coitions are observed to take place only after the three-hundredth generation. Before that time the Infusoria may be placed in all the other conditions favorable to copulation, without being seen to contract a single union. On the other hand, beyond that time, a period extends in which numerous coitions are obtained. Although, indeed, the cyclical alternation of agamic generations and copulations is indisputable, further researches are still necessary to obtain a thorough knowledge of the extent of these cycles. It is certain that their duration varies in the

different species, and perhaps, in conditions as yet imperfectly known, may in any one species be considerably abridged.

We are now come to the preliminaries of copulation. We have described them in our work, making use of the observations of Balbiani, Gruber, and of Engelmann, some of which we found confirmed by Bütschli. M. Maupas, who has recently again taken up this question, believes he has discovered in his predecessors, or rather in the observations of M. Balbiani, grave errors. I shall transcribe the passage in question: "When a numerous group of Infusoria of the same species are found in the conditions that determine copulation, these animalcula abandon themselves to certain movements, and exhibit an agitation the significance of which has been much exaggerated. Balbiani, who in fact always seeks analogies with the higher animals, has given us an animated description of these movements, to which a poetical imagination has contributed at least as much as exact and scientific observation. This description has met with a most favorable reception among certain philosophers and psychologists who have taken up with it in the belief that they could thereby reveal in microzoans the rudiments of the instincts and psychic faculties of higher-organized beings. As there is very much inexactitude and exaggeration in all that, it is time to calm this enthusiasm and to refer the facts and their explanation to some more exact criterion." (Page 413.)

I believe it useless to occupy my time in dealing with the aggressive tone that this author has seen fit to assume towards me, and which seems to be habitual with him when he criticises the works of people with whom he does not agree. I shall carefully examine his observations and seek to derive from them some profit, to the improvement and correction of my work upon the Psychic Life of Micro-Organisms, if it is true that I have committed the grave errors of which he speaks. Besides, the question of the preliminaries of copulation is so interesting in itself that I have no fear of turning to it a second time.

It is necessary, here, clearly to distinguish two things: the facts and their explanations. In that which concerns observed facts, the errors that M. Maupas endeavors to point out in the

descriptions of M. Balbiani appear to me to be capable of a reduction to a matter of so little significance—admitting that it comes at all from error—that if I had not been apprised of it, I should have regarded the researches of the first author as a confirmation in most details of those of the second. It is to be observed, in fact, that M. Maupas gives almost the same description that Balbiani does of the movements of *Paramœcium aurelia*. "I have followed animals of that species a number of times," he says, "during the preparations for copulation. They exhibit at that moment a very great agitation. They are seen to go and come, rapidly changing their direction. They approach and throw themselves against their congeners, halt in front of them, feel them an instant with their cilia, then leave them, assume the most varied positions, and, finally, when two individuals equally ready for union chance to meet each other, they face about by their anterior extremities so that the two bodies come together and join, with the exception of the posterior extremities, along their whole extent; the union is thus definitively effected."

Up to this point, let it be observed, our author's description is but a paraphrase of that of M. Balbiani, which we have given on page 69 of our work; and a simple comparison of the two suffices to prove this. The divergences of fact extend, as it seems to me, to the two following points only: The duration of the preliminaries, and the existence of an epidemic of copulation. M. Maupas thinks that the movements in question never last very long, at the most a quarter of or half an hour among individuals that have arrived at karyogamic maturity. Whereas M. Balbiani has observed these same movements last for several days. I do not know which of these two observations is the more exact; in fact, I do not think it necessary to choose between them, since both may be exact, the duration of the phenomenon generally being dependent upon conditions subject to great change, while M. Maupas himself remarks that the ciliate Infusoria in the variability of all their biological phenomena are veritable thermometers of a very great sensibility. However that may be, whether the movements that precede copulation in *Paramœcium* last a quarter of an hour, half an hour, or several

days, that fact does not change their real character. The second divergence relates to the epidemics of copulation in the case of *Paramæcium aurelia;* observed by M. Balbiani and denied by M. Maupas. "All the individuals of a group," says M. Maupas, "are never found simultaneously in this condition. Hence the tentative preliminaries of copulation, that fail in their object and end in the individuals going to seek elsewhere another partner." I confess, I do not understand this statement, involving, as it does, M. Maupas in a contradiction; for two pages before this he speaks of the mode of the appearance of copulation as in the epidemic form. All observers, he says, that have occupied themselves with this phenomenon, state that it is suddenly developed in the little aquariums in which the animals are contained, and very rapidly becomes general (page 41).

To this then the divergences of fact are reduced—a matter entirely insignificant; and I believe it useless to dwell upon it longer. The question of interpretation remains. I shall also say a few words with reference to this, although the disagreement is at bottom not much more serious.

We have seen, that, according to M. Maupas, the Infusoria do not seek each other and copulate until after a fast of considerable duration caused by exhaustion of the store of food in the medium in which they live. The author concludes from this that scarcity of food is the sole and real cause of the great agitation in which they are then seen. "When an infusion thickly populated begins to get exhausted, the animalcula congregate together, always forming those whitish cloud-spots that we have described as the prelude to copulation. . . . Not until afterwards do the actual movements of copulation occur, which never last very long." Accordingly, there is first an agitation produced by hunger, and only in consequence of that are the preliminaries of copulation brought about. Admitting this interpretation as exact, which is indeed a question that I reserve, I conclude that M. Maupas completely accepts the facts of the preliminaries of copulation, distinguishing them from other phenomena that precede them. He says, moreover, and these are his own words, that the sexual impulse does indeed exist in these little creatures. Unquestionably he is right in adding that this sexual impulse pre-

sents in the ciliate Infusoria manifestations much simpler than in the higher animals, and that it is otherwise in accord with their simplicity of organisation. That is evident, and no one I believe has ever maintained the contrary.

Finally, the author refuses to admit that the sexual manifestations of the Infusoria can be compared with the phenomena of *rut*. "Rut," he says, "the external and psychic manifestations of which we know with any degree of exactitude only in mammals, is a reflex phenomenon concomitant with and consecutive to the maturation of the Graafian vesicles. It is therefore an especial phenomenon peculiar to the females of the highest group of the animal series. Males are not subject to rut, but are always ready to experience the sexual excitation whenever they find themselves in contact with females that are fallen into that condition" (page 414).

Naturalists will certainly read with great astonishment this definition of rut, which is wholly new and personal to the author. Hitherto the word rut has not been reserved for mammals; it has been applied to all classes of animals, even to the lowest, and Duvernoy, for example, has devoted an article to the rut of zoöphytes.

We now come, following the chronological order of the phenomena, to the material processes of conjugation, otherwise called fecundation, in the ciliate Infusoria. It is needless to take up in its entirety a question that we have already examined, and which will be found treated of at page 65 of our work. But it is certainly interesting to dwell upon the general significance of the question of fecundation. It is known that all ciliate Infusoria, excepting some species such as *Opalina*, a parasitic infusory of the frog, exhibit in their protoplasm two kinds of nuclear corpuscles. First a nucleus, a principal nucleus, which the authors designate by the names endoplast and macronucleus; this element is in some ways comparable to the nucleus of the cells of tissues. Besides this the ciliate Infusoria possess a smaller nuclear element than the former, called by the authors nucleolus, or endoplastule, or attendant nucleus, or finally micronucleus. This micronucleus comprises in its evolution the internal phenomena of the process of conjugation. The principal nucleus plays in the process but an accessory rôle,

for it is a wasted element destined to be replaced by a nucleus of new formation; when it undergoes more or less complete elimination. The attendant nucleus passes through a series of complicated modifications which vary much in detail for each species. First, there are stages of division destined to prepare the way for the elimination of the used up corpuscles. But the most important fact is that at a given moment there exists in the protoplasm of each ciliate Infusory in conjugation, two corpuscles derived from the nucleus; then an exchange is effected between the two individuals in copulation; each transmits to the other one of the corpuscles, which copulates with the remaining corpuscle left in the interior of the body. These two little nuclei that play parts so different are, according to M. Maupas, completely identical with one another and do not show the least difference either in form, volume, or structure. "In the twelve species in which I have succeeded in closely studying these organs," says that author, "I have always seen them act with the most perfect similitude under the influence of coloring and fixitive re-agents." Nevertheless, in view of the future condition of these two elements, M. Maupas is led to give them the very significant names of male pronucleus and female pronucleus. The female pronucleus is the one that remains immobile in the body of the parent gamete; while the other, the male, is exchanged and passes into the body of the other gamete.

In what does the real nature of the copulation of these two pronuclei consist? Does it consist in a fusion of the elements mentioned, or, indeed, do the latter preserve their original independence and autonomy in the midst of the new mixed nucleus, standing in juxtaposition with and moving in and about one another? This is the question that M. Maupas immediately proceeded to examine. The recent researches of M. Ed. Van Beneden upon the internal mechanism of fecundation in *Ascaris megalocephala* are well known. We have published in the *Revue Philosophique*, following M. Balbiani, a résumé of these important investigations, and we may be permitted to reproduce here a few passages therefrom; for nothing is more interesting than the evolution followed by our ideas in that which concerns fecundation.

The notions that were formed of this phenomenon only took definite and precise shape from the time when the existence of the two elements of fecundation, the spermatozoön and the ovum, could be established. It was at first believed that the spermatozoön impregnated the ovum by the exercise of a purely physical action—an action of contact and influence. But observation demonstrated that something more took place, namely, an actual conjugation, a union, a blending of the spermatozoön and the ovule. A further step was made in 1875, when it was discovered, in studying the ova of Echinoderms, that but one single part of the ovule, the germinative vesicle, conjugated with but one part of the spermatozoön, namely the head, and that since these two elements have each the value of a nucleus, fecundation consisted in the conjugation of two nuclei. But there was still an element of obscurity in this idea, simple as it was. If the nuclei were vesicles like soap-bubbles they might burst, the one within the other; but the nucleus contains a great number of differentiated elements, the chromatic reticulated substance, the nuclear substance, the nucleoli, etc.: what becomes of all these elements during the conjugation of the two nuclei? In 1881, Flemming made a new advance in the question. He determined more precisely the nature of the fusion of the two pronuclei, establishing that it consisted in the blending of their chromatic substances. This he observed in the ova of the Echinoderms. According to the very recent works of M. Van Beneden upon *Ascaris megalocephala*, the great nematoid of the horse, there is no fusion whatever between the two pronuclei. They always remain distinct. Each passes through, separately, all the phases of karyokinesis, when the fecundated ovum divides. In this connection the recent observations of M. Balbiani confirm the opinion of Van Beneden, who had been sharply attacked by Carnoy and Zacharias. First, in each of the two pronuclei each reticulate substance is observed to present the initial phases of karyokinesis; the net-works form into a skein that contracts and thickens; the ribbon-like body thus formed divides into two segments, which bend so as to form acute-angled crooks or loops. There are thus produced two loops in the male pronucleus, and two in the female pronucleus. Then the two

male loops approach the two female loops in a manner such that a sort of star is formed with eight branches turned towards the periphery of the ovum (nuclear or equatorial disk). Then the fecundated ovum begins to divide into segments. Now at every new equatorial stage of the subsequent divisions of the ovum these four loops are seen to reappear in such a manner that fusion never takes place between the male element and the female element. Each of the four primitive chromatic loops divides by longitudinal division into two secondary loops, whence result two equatorial semi-disks, each formed of four secondary loops, of which two come from the male pronucleus and two from the female pronucleus. Each of the two new nuclei contains therefore a certain number of male and female chromatic loops, and consequently presents an hermaphroditic constitution.

For Van Beneden, therefore, fecundation consists essentially in the presence in the ovum of two nuclei, one male and one female. The conjugation of the two nuclei is a phenomenon of no importance; it may take place, or it may not. The physiological signification of fecundation is a process of rejuvenation, in which the ovum replaces its old male element with a new male element, the spermatozoön.*

M. Maupas remarks that the pronuclei of the Infusoria by reason of their complicated structures do not admit of these difficult investigations. Nevertheless he mentions the fact that these pronuclei are, in the elements mentioned, composed of two distinct substances, hyaloplasm and chromatin. He puts forth the opinion that the hyaloplasm constitutes an accessory portion, and that the chromatin is endowed with the fecundative properties. Which means that in certain ciliate Infusoria the male pronucleus at the moment of its migration is composed solely of chromatin. Finally, M. Maupas arrives at the conclusion that the supreme end of fecundationis the renovation, the reconstitution, of a rejuvenated nucleus formed by the copulation of two fecundative nuclei having distinct origins

* *Recherches sur la Maturation de l'Œuf, etc. Arch. de Biol. Vol. iv. 1883. Nouvelles Recherches sur la Fécondation. Bul. de l'Acad. Roy. des Sciences de Belgique, 3 Série, Vol. xiv. 1887.*

and of which the chromatin elements represent the essential part (page 434).

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It is now time to return a moment to the theory of Weismann and to see if it has not been shaken by the new data that we have just placed before the reader. Accepting the results of the experiments of M. Maupas, who, as a matter of fact, has arrived at the same conclusions as M. Balbiani, we are led to the admission that when a ciliate Infusorian multiplies by agamic division a great number of times, the offspring that appear after from 50 to 100 bipartitions has not the same physiological value as its original progenitor; and that agamic multiplication ends in exhaustion and in natural death. But it must, on the other hand, be taken into account that this process of senescence is counteracted by that of conjugation, which consists in a nuclear renovation; and since the substance, the protoplasm, of the rejuvenated individual escapes death, a new argument might be found in these last mentioned facts for the theory of the immortality of Infusoria.

The question is, at bottom, whether the individual after conjugation is identically the same as before conjugation, or whether it constitutes a new animal. In that the solution rests. Now, the new element that the individual acquires by the act of conjugation is the male pronucleus of its partner. In addition it loses the greater part of its old accessory nucleus and the whole of its old principal nucleus. In return, by way of compensation, it preserves the integrity of its protoplasm and of its other organs. M. Gruber believes that physical identity persists in spite of these modifications. M. Maupas maintains the contrary.

It seems to us that a question of this character does not admit of a satisfactory solution, and this opinion will be shared by all who have considered the idea of physical identity. It is a notion obscure, uncertain, and full of contradictions. We have formed it because it answers our practical needs. But it is certainly evident that it corresponds to no well defined external phenomenon. In fact, we understand by physical identity the constant reunion of certain elements in a certain order. If the order of these elements is very

slightly modified, or if a very small number of these elements is replaced by others, we do not hesitate to say that the physical identity in question has not been altered by these insignificant modifications. If, on the other hand, the order has been almost totally destroyed, if the greater portion of the elements has been renewed, we should, on the contrary, say that the identity of the thing in question had been lost in these alterations and that a new object had replaced the old. Replace a stone in a house and the latter remains the same house; rebuild the house upon a new plan and with different materials retaining very little of the first construction, and it is a different house. But between these two extreme cases there is a whole series of possible intermediate changes, and we are not able to establish clearly by any exterior mark the point where physical identity ends. This is a matter of personal estimation; I might even say of caprice; and all the discussions raised upon these questions appear to me wholly idle.

I believe, accordingly, that the thesis of Weismann regarding the immortality of Infusoria eludes a direct refutation. It is neither confirmed nor overturned by observed facts.

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